RELATION OF PLANTS TO ENVIRONMENT

(OR PLANT ECOLOGY)

OUTLINES OF COURSE OF LECTURES

Delivered in the

Summer School of Cornell University

1903 and 1904

By

GEO. F. ATKINSON

Ithaca, New York

June, 1904

Dr. W. G. Farlow
with the [illegible] author

Relation of Plants to Environment

(or Plant Ecology)

Outlines of a Course of Lectures

Delivered in the

Summer School of Cornell University

1903 and 1904

By Geo. F. Atkinson
Professor of Botany in Cornell University

Published by the Author
Ithaca, N. Y.
June 1904

BOOKS BY THE AUTHOR

The Study of the Biology of Ferns, by the Collodion Method. Large 8vo pp. I-XII+1-134. 163 figs. Macmillan & Co., New York, 1894. Price $2.00 (Out of print).

Elementary Botany. 2nd Edition, pp. I-XXIII+1-444. 508 figs. Henry Holt & Co., New York, 1899. Price $1.25.

Lessons in Botany. pp. I-XV+1-365. 277 figs. Henry Holt & Co.. 1900. Price $1.10.

First Studies of Plant Life. pp. I-XII+1-276. 308 figs. Ginn & Co., Boston, 1903.. Price 60 cents. 70 cents by mail.

Studies of American Fungi; Mushrooms, Edible, Poisonous, etc. pp. I-VI+1-322, 86 plates, 8 colored 238 figs. 2nd Edition, Andrus & Church, Ithaca, 1901. Henry Holt & Co., New York, 1903. Price $3.00 net.

1st Edition. pp. I-VI+1-275, 76 plates, 8 colored, 223 figs. Andrus & Church, 1900. Price $2.00.

Relation of Plants to Environment, or Plant Ecology, Outlines. pp. 67, 1904. Price 75 cts.

TABLE OF CONTENTS

Relation of Plants to Environment

(or Plant Ecology)

I. THE ORGANIZATION OF THE PLANT.

Earliest plants simple in form and structure.

1. Earliest found among lower algae and fungi.
   Naked protoplasm, red snow plant, Pleurococcus, bacteria.
   Pandorina, Spirogyra, Oedogonium.
2. Adjustment to environment not difficult.
   1. Surrounded by food solutions easily absorbed.
   2. No problem of food transportation.
   3. The larger the organism the greater the problems.
   4. Soon differentiation in work of protoplasts—
      Absorption.
      Conduction.
      Light relation.
      Reproduction.
   5. Gain in splitting body into parts
      1st, Larger surface exposed to environment.
      2nd, Economy in building material.
   6. Two problems—
      1st, Ready display of larger surface for acquiring food and disposition of waste.
      2nd, Protection of plant from injuries or austere environment.

Variety of conditions developed variety of forms.

Plants no consciousness or choice in general sense.

"Inherent" quality.

"Environment"

"Sexual selection", etc.

Examples, cactus, yucca, cucurbits, oak.

Process of organization and change of form a slow one.

Members of the plant body.

Simplest forms do not have members.

Members recognized when certain parts perform certain functions.

Algae, fungi, sea wrack or ulva.

Fond=thallus.

Thallophytes or thallus plants.

Liverworts or mosses.

Duckweeds.

Great variety in form and function of members.

Reducible to three forms—

1. Root.
2. Stem.
3. Leaf.

Reduced by some to two—

1. Root.
2. Shoot.

Plant body { Shoot { Stem / Leaf } / Root }

Kinds of shoots. For convenience treat of four kinds.

(1) Foliage shoots.
(2) Shoots without foliage leaves.
(3) Winter conditions of shoots and buds; annual growth.
(4) Flower shoots.

II. ORGANIZATION OF PLANT TISSUES.

A tissue is a group of cells of same kind having a similar position and function.

Differentiation of labor.

Mestome, tissues for conduction.

Stereome, tissues for mechanical support.

So differentiation for absorption, assimilation, perception, reproduction, etc.

Tissue systems, 3—

1. Fundamental System.

Parenchyma.
Collenchyma.
Sclerenchyma.

Cork (phellogen or "cork cambium")
Suberin prevents cork from wetting.
Lenticels, at stoma on stem, cork beneath.

2. Fibrovascular System.

Fibrous tissue.
(Some occurs in fundamental system
ex., bundle sheaths, strands in cortex).
Vascular, or tracheary tissue.
Sieve tissue.
Fascicular cambium.

3. Epidermal System.

Epidermis.
Trichomes, etc.

4. Origin of Tissues.

Meristem tissue.
Stem apex, Root apex } produce primary tissues.
Cylinder of cambium, produces secondary tissues.
Origin of stem tissues.
Dermatogen—epidermis.
Plerome—central cylinder or stele.
Periblem—cortex.
Central cylinder or stele.
Pith.
Bundles { xylem, phloem
Medullary rays.
Pericycle.
Bundles.
Collateral—Dicotyledons and Conifers,—open { xylem. cambium. phloem.
Concentric—Monocotyledons and Ferns,—closed { xylem. phloem.
Radial—roots.
Origin of root tissues.
Calyptrogen in addition to those in stem.

III. THE DIFFERENT TYPES OF STEMS.

1. Erect Stems.

Columnar or cylindrical type.

1. Simple or branched,
   Sunflower, mullein, Lombardy poplar, royal palm, tree ferns, some cedars, arbor vitae.
2. Advantages of the columnar habit.
   (1) More favorable light relation.
   (2) Maintain same habit when with others as when alone.
   (3) Less competition for existence.

Cone type.

1. Main axis like a tall shaft.
2. Branching of two types—
   (1) False whorls
   Pines.
   Norway spruce.
   Douglas spruce.
   White pine.
   Growth movements of young stems { Elongation of shoot. Elongation of leaves.
   Rate of growth—year marks.
   (2) Spiral or distributed.
   Hemlock spruce, Larch.
   (3) Advantages of the cone type.
   1. Less injury during high winds.
   2. Admit light to a larger foliage area.
   3. Less danger of injury from weight of snow.

Oval type.

Examples, oak, chestnut, apple.

1. Main axis usually disappears.
2. Exhibit character of habit best during winter.
3. Not so well adapted to higher altitudes and latitudes.
4. Deciduous habit enables them to withstand winds better.

Deliquescent type.

Example—elm.

Main axis and branches fork by false dichotomy.

Advantages of trees over less lofty vegetation.

1. Outgrow other kinds.
2. Shade the ground and drive out sun loving kinds.

Prostrate type.

1. Strawberry.
2. Certain roses—Japanese rose (Rosa wichuriana).
3. Some raspberries.
4. Cucurbits—squash, melons, pumpkins, etc.
5. Economy in stem building.
6. Advantages—
    a. Protected from wind and cold.
    b. Propagate themselves by rooting here and there.

Decumbent type.

Stem erect at first, later bending in form of arch. Takes root where tip touches ground.

Examples,

Some raspberries.
Some blackberries.

Climbing type.

Examples, grapes, clematis, some roses, ivies, trumpet creeper, climbing bittersweet.

1. Economize in material for stem building.
2. Sometimes develop foliage sufficient to nearly smother foliage of large trees.

Floating stems. Aquatic plants.

1. Stems ascending or horizonal.
2. Not large or strong. Water supports them.
3. Potamogeton. Myriophyllum.
4. Algae.
    (1) Fresh water, Chara, Nitella.
    (2) In ocean, Sargassum, Macrocystis.
        In these the plant body is a thallus divided into stem (caulidium) and leaf (phyllidium).

Burrowing type or rhizomes.

1. Horizontal, subterranean stems.
    Examples, bracken fern, sensitive fern, mandrake, solomon's seal, Trillium, Dentaria.
2. In ferns subterranean is only shoot; bears scale leaves

devoid of chlorophyll, also subterranean; and foliage leaves, larger and aerial. Flowers not formed.

3. Mandrake, Solomon's seal, Trillium, have scale leaves on fleshy underground stem; foliage leaves on aerial stems, bearing flowers.
4. Grasses.
5. Advantages of subterranean habit:
   (1) Protection from cold.
   (2) Protection from wind.
   (3) Protection from injury by certain animals.
   (4) Local migration.
   (5) Food storage in many forms.
   (6) Propagation.

Specialized Shoots for Storage of food.

Bulbs.

1. Underground.
2. Aerial.

Examples, Easter lily, Chinese lilies, onion, tulip.

Corms.

Examples, Jack-in-the-pulpit (Arisaema)

Tubers.

Example, potato (Irish, not sweet).

"Eyes" are buds on stem from which aerial shoots arise.

Use—contains food for young sprouts.

Undifferentiated stems.

Examples, duckweed, Lemna, Wolffia.

IV.—FOLIAGE LEAVES

Influence of foliage leaves on the form of the stem.

Exercises great influence on form of stem.

Without foliage leaves stems of green plants would develop different habits. Development would take place in three directions under influence of light—

1. Profuse branching—Asparagus.
2. Fewer branches and flattened.
3. Massive trunks with few or no branches.

Relation of foliage leaves to the stem.

Phyllotaxy or arrangement of leaves.

1. Note scars on winter shoots of woody plants.

2. Largei number arranged alternately—elm.
3. Angles of divergence.
4. Adaptation in leaf arrangement. Influenced by environment.

Two modes of distribution—

1. Phyllotaxy, distribution along individual stem.
2. Distribution with reference to plant as a whole.
   (1) Primarily a light relation.
   (2) Comparison of different trees, elm, Norway maple, sugar maple, red maple, silver maple, locust.

Color of foliage leaves.

Majority green; due to chlorophyll.

Light necessay for production of chlorophyll.

Other colors; red (Rosa rubrifolia), purple (purple barberry, hazel, beech, birch), yellow (golden oak, elder). All possess chlorophyll in addition.

Autumn colors.

1. More marked in some trees than in others.
2. Red, in red maple, red and scarlet oak, sourwood.
3. Yellow in sugar maples, poplars, hickories.
4. Sweet gum.
5. Red and purple suffused in cell sap as in cells of red beet.
6. Yellow due to disappearance and degeneration of chlorophyll.
7. Yellowing of crops.
8. Blanching grass. Celery.
9. Theories concerning autumn coloring.

   1st, attributed to

   1. Frost.
   2. Action of more oblique rays of sun.
   3. Diminishing water supply.

   2nd, question obscure one.

   Low temperature.
   Declining actvities of leaf.
   Different soil.
   Different climate.

   3rd, North American forests.

Variety of species.
Number of species.

4th, red color as a means of increasing temperature?
red color as a screen to protect from light?

Function of foliage leaves,—five-fold,—

1. Carbon-dioxide assimilation, or photosynthesis.
2. Transpiration.
3. Synthesis of other organic compounds.
4. Respiration.
5. Assimilation.

Parts of the leaf.

1. Blade or lamina.
2. Stalk or petiole.
3. Stipules, elm, magnolia, etc.
4. Sometimes hairs, scales, etc.

Note sessile leaves.

Simple leaves.

1. Form of leaf usually constant for given species.
2. Outline of leaf, ovate, oval, elliptical, lanceolate, linear, needle-like, etc.
3. Advantage of simple leaf—amount of surface to light.
4. Disadvantage of simple leaf when large.
   (1) Casts deeper shade.
   (2) Does not admit as free circulation of air.
   (3) More apt to become injured.

Venation of leaves,—two types,—

1. Parallel veined, usually monocotyledonous plants.
   Corn, Smilacina, Solomon's seal.
2. Netted veined, usually dicotyledonous plants.
   Elm, rose,maple, hawthorn, oak.
   (1) Palmate.
   (2) Pinnate.

Cut or lobed leaves, some maples, oaks, birches, poison ivy, thistles, dandelion.

Divided or compound leaves, rose, sumac, elder, hickory, walnut, locust, pea, clover, American creeper.

Significance of forms.

1. Reduction of surface allows
   (1) Freer movement of air.

(2) Greater protection from wind.

2. Mid vein in hickory, walnut, locust, and primary lateral veins in Kentucky coffee tree, serve in place of terminal branches of stem. Compare hickory, horse-chestnut, ailanthus, walnut and butternut, sumach.

Advantages of compound leaves.

3. Light relation.

General structure of leaf.

1. Upper and lower surface cells devoid of chlorophyll.
2. Mesophyll layer of palisade cells beneath epidermis.
   Loose parenchyma with intercellular spaces.
3. Veins contain conduits for water, salts and food stuffs.
4. Stomata protected by guard cells.

Protection of leaves.

I. Protective modifications.

1. Structural adaptations.

(a) Palisade layer of cells acts as light screen, aids in lessening loss of water. Change in palisade layer as a protection against intense light. Compass plant.

(b) Stomata close to prevent loss of too much water.

2. Protective covering.

(1) Epidermis and cuticle.
Thickening of walls.
Protection against too great loss of water.
Protection against too much water, cabbage, carnation.

(2) Covers of hairs or scales.
Lessen loss of water vapor.
Spines protection against animals.

3. Reduction of surface.

(1) Reduction of surface with reduction of mass. See (1) over.

(2) Reduction of surface inversely as the mass. See (2) over.

(1) a. Dissected leaves of aquatic plants.
b. Lobed and aerial leaves.
c. Needle leaves of conifers.

(2) Examples, leaves of Juniper, Arbor vitae, Cypress, yucca, Cassiope, Pyxidanthera, Live-forever.

4. Elimination of the leaf.
Cacti, Phylloclades.
Stem contains the chlorophyll, provides water storage.

II. Protective positions.

(1) Leaves arranged in relation to ground, each other, or to give protection from too great radiation.
Cassiope, Pyxidanthera, juniper, arctic plants.

(2) Position affected by light stimulus, day and night positions, Leguminosae, Mimosa, compass plant.

Relation of leaves to light, Heliotropism.

Day and night positions contrasted.

Profile—a protective position.

1. Those with pulvinus, clovers, peas, beans, oxalis, telegraph plant.
2. Those without pulvinus due to epinastic growth or caused by light.

Leaves which rotate with the sun.

Sunflower, young seedlings, Cassia marilandica, cotton plant.

Fixed position of old leaves.

Position on horizontal stems.

Relation of stem, petiole and blade.

Position of leaflets on divided leaves.

Compare entire leaf, compound leaf, dissected leaves, millfoil, aquatic plants.

Mosaics, or close patterns, Fittonia.

Advantage of mosaic arrangement.

Leaves do not shade each other.

Permit circulation of air.

1. Rosette pattern, Gloxinia.
2. Vines and climbers, ivies, Pellonia, trailing ribbon grass.

Branch patterns, maple, pattern made during growth of leaves,

Tree pattern, weeping elm, conifers.

Imbricate pattern of short stems.

Compare with rosette pattern, begonias.

Spiral patterns, sunflower, mullein, chrysanthemum, Easter lily.

Radiate pattern, grasses, dragon tree.

Plants with narrow leaves and short stems.

Cycads, palms, many ferns.

Compass plants, vertical leaf arrangement.

Open patterns.

Presented by divided or branched leaves.

Leaves next ground often entire or less divided.

V. THE ROOT.

Functions of the root.

1. Anchorage and partial support.
2. Absorption of liquid nutriment from the soil.

Problems for solution by the plant.

1. Permeation of the soil or substratum.
2. Grappling the substratum.
3. A congenial moisture or water relation.
4. Distribution of roots for the purpose of reaching food laden soil.
5. Exposure of surface for absorption.
6. The renewal of the delicate structures for absorption.
7. Aid in preparation of food from raw material.
8. The maintenance of the required balance between the environment as a whole and the increasing or changing requirements of the plant.

Correlation between root system of a plant and the form of the stem system and position of the leaves., as in,

1. Radiate type of leaf system of dandelion, beet, etc.
2. Imbricate type as in broad leaved trees, and in the overlapping branch system of many pines, etc.

This generalization is not necessarily correct, for as in the latter class,

1. Root and leaf distribution are governed by other and more important laws.
2. In light rains the leaf surface holds back practically all the water.
3. In heavy and long continued rains the water breaks through the leaf system.
4. Habit of plants to grow in dense societies.

Kinds of roots.

1. Fibrous root system.
2. Tap root system.
3. Aerial roots, for purposes of
   (1) Absorption of moisture from the air
   (2) Support.
4. Bracing or prop roots.
5. Buttresses.
6. Fleshy roots, or root tubers.
7. Water roots and roots of water plants.
8. Holdfasts.
9. Haustoria or suckers.
10. Rootlets or rhizoids.

VI. THE FLOWER SHOOT.

1. Parts of the Flower.

The flower.

Complete flower, buttercup, blood root, apple, rose, etc.

Two sets of members, or organs, attached to the receptacle or torus.

1. Floral envelope.
2. Essential or necessary members or organs.

Floral envelopes—(homology)

1. Calyx (sepals) chiefly protective.
2. Corolla (petals), two functions
   (1) Protection.
   (2) Attract insects.

Essential organs.

1. Androecium (stamens), homology.
2. Gynoecium (carpels), homology.

Purpose of the flower.

Stamens (=microsporophylls) are organs for production of pollen, or pollenspores (=microspores.)

Stalk(=filament) not always present.

Anther.

Anther sac, or pollen sac (=microsporangium).

Pistil consists of ovary (contains the ovules), style (not always present), stigma.

A simple pistil=a carpel=macrosporophyll.

A compound pistil=several carpels joined.

Ovule=macrosporangium.

2. Kinds of Flowers.

Complete flowers.

Incomplete flowers.

Apetalous flowers.

Naked flowers.

Staminate flowers.

Pistillate flowers.

Sterile flowers.

Perfect flowers (hermaphrodite).

Imperfect or diclinous flowers.

Monoecious flowers.

Dioecious flowers.

Polygamous flowers.

Forms of flowers, regular or irregular.

Forms of corolla,

1. Rotate (potato, tomato, bittersweet).
2. Salver-shaped (phlox).
3. Campanulate (hare-bell or Campanula).
4. Tubular (trumpet flower or disk florets of composites).
5. Butterfly or papilionaceous (pea, bean).
6. Labiate (flowers of mint family).
7. Personate or masked (toad flax, or snap dragon).
8. Ligulate, or strap-shaped (dandelion, chicory, or ray florets of other composites).

When the parts of the flower are separate.

1. Calyx is polysepalous.
2. Corolla is polypetalous.
3. Stamens are distinct.
4. Pistils are simple.

When parts of the same series are united.

1. The calyx is gamosepalous.
2. The corolla is gamopetalous.
3. The stamens are syngenoesius.
4. The pistil is compound.

Syngenoesious stamens are

1. Monadelphous (hollyhock, cotton, mallow, etc.)
2. Diadelphous (pea, etc.).
3. Triadelphous (Hypericum).

Compound pistil, the two or more carpels are united.

1. Each cavity is a locule.
2. Sometimes all the walls disappear and there is a common cavity (purslane, chickweed, pinks, etc.).
3. False partition in few cases (crucifers).

Union of parts of different series=*adnation.*

Terms hypogynous, epigynous, perigynous, superior, inferior.

3. Arrangement of Flowers or Mode of Infloresence.

Flowers are solitary or clustered.

Flower clusters.

Solitary flowers are axillary or terminal and separated by foliage leaves.

There are two modes of infloresence.

1. Corymbose, or indeterminate; axillary flowers.
2. Cymose, or determinate; terminal flowers.

Flower clusters with indeterminate inflorescence.

1. Raceme (choke-cherry, currant, pokeweed etc.).
   Compound raceme as in Smilacina racemosa.
2. Panicle, by branching of lateral flower axes of a raceme (oat).
3. Thyrsus, compact panicle of pyramidal form (lilac, horsechestnut).
4. Corymb.
   Simple corymb.

Compound corymb (mountain ash).

5. Umbel, simple and compound.
6. Spike (mullein, plantain).
7. Head, or capitulum.
8. Spadix, surrounded by a spathe.
9. Catkin, or ament.

Anthesis of corymbose flower cluster is centripetal.

Flower clusters with determinate inflorescence.

1. Cyme,
   Simple cymes as in basswood.
   Compound cymes as in dogwood, hydrangea, etc.
2. Helicoid cyme, (forget-me-not).
3. Scorpioid cyme.
4. Forking cyme (chickweed).

Anthesis of cymose inflorescence is centrifugal.

VII POLLINATION

Self pollination, or close pollination.

Cross pollination.

1. Wind pollination (anemophilous flowers).
2. Pollination by insects.
   (1) Nectar.
   (2) Flower colors.
   (3) "Guides."

Dichogamous flowers (bluet, primrose).

Proterandry and proterogeny (Campanula, skunk's cabbage, etc.).

Dioecious flowers.

Mechanisms for throwing pollen on insects.

Kalmia.

Cytisus.

Certain orchids (Catasetum saccatum).

Pollinium (disc, pedicel, pollen masses).

"Antennae"

Stigmatic chamber.

Labellum.

Pollination of orchids, Cypripedium, Epipactis, etc.

Pollination of the canna.

Pollination of Yucca by Pronuba.

VIII THE FRUIT

Fruit consists of ripened ovary in addition to seed, and in many cases with accessory parts as calyx, receptacle, etc., combined with it.

Pericarp, part of the fruit which envelops seed.

1. Carpels alone, or
2. Carpels and adherent part of receptacle, or calyx.
3. In many fruits pericarp differentiated into layers as in peach, cherry, etc.
   (1) Exocarp (outer), endocarp (inner).
   (2) Sometimes three layers are recognized.
   a. Epicarp (skin) } { More often
   b. Mesocarp (intermediate) } { as exocarp.
   c. Endocarp (inner)

Fruits are "dry" or "fleshy." Two kinds of dry fruits.

1. Indehiscent, those which do not open at maturity.
2. Dehiscent, those which open at maturity.

Indehiscent Fruits.

The akene (buttercup, composite family, etc.)

The samara, or key fruit (elm, maple, etc.)

The caryopsis, the seed is consolidated with the wall of the ovary, wheat, corn, and other grasses.

The schizocarp, a dry fruit of several locules separating at maturity (Umbel and mallow family).

The acorn fruit (oaks), consists of the acorn and "cup" (cup formed from consolidated involucre).

The hazelnut, chestnut, and beechnut. The involucre forms a husk or bur which surrounds the nut.

In the beechnut and chestnut the "bur" dehisces.

The hickory nut, walnut and butternut.

Hickory nut, the "shuck" consists partly of calyx and partly of involucral bracts consolidated. The shuck dehisces.

The "hull" of walnut and butternut probably the same origin as in hickory nut, but it does not dehisce.

Walnut and butternut sometimes called "stone fruits" or "drupes."

2. Dehiscent Fruits.

Dehiscent fruits are sometimes called in general, pods or capsules; pericarp is dry.

1. If pistil is simple (gynoecium apocarpous), there is a single carpel.
2. If the pistil is compound (gynoecium syncarpous), several carpels are united.

Syncarpous capsules may dehisce in three ways,

1st, septicidal dehiscence (azalea, rhododendron).

2nd, loculicidal dehiscence (iris, lily, etc.)

3rd, poricidal dehiscence (poppy).

Syncarpous capsules with one locule (bouncing Bet).

Apocarpous capsules

1. The follicle splits along both sutures (pea, bean).
2. The silique (most crucifers), when short it is a silicle or pouch.
3. The pyxidium, or pyxis, opens with lid, (plantain).

3. Fleshy and Juicy Fruits.

The drupe, or stone fruit (cherry, peach, etc.)

Pericarp { exocarp becomes fleshy
endocarp becomes hard and stony and encloses seed or "pit."

The raspberry and blackberry, collective or aggregate fruits.

Each ovary forms a druplet.

In raspberry fruit separates from receptacle.

In blackberry and dewberry fruit remains attached to receptacle.

The berry. In true berry both exocarp and endocarp are fleshy (cranberries, gooseberries, currants, tomatoes, etc.)

4. Reinforced, or Accessory Fruits.

The torus or receptacle is grown to the pericarp in fruit.

The strawberry, the seeds are sunk in fleshy enlarged receptacle.

The apple, pear, quince, etc. (a pome).

1. The receptacle is consolidated with the ovary, and the calyx and stamens on margin of receptacle.
2. The receptacle and outer part of pericarp becomes fleshy, while inner portion of pericarp becomes papery and forms "core."

3. The rose fruit is called a "hip."

The pepo (squash, pumpkin, etc.)

The receptacle is consolidated with the outer part of the three loculed ovary.

5. Fruits of Gymnosperms.

The cone fruit.

Fleshy fruits of gymnosperms.

1. Cedar berries, fleshy part from outer wall of ovules, stony part from inner wall.
2. The yew "berries."
   (1) Stony seed from the single ovule.
   (2) Fleshy outer part from the "aril," or outer integument.
3. Fruit of ginkgo, a ripened ovule.
   (1) Outer layer soft.
   (2) Inner layer hard.
   (3) The "collar" at the base of the fruit is a rudimentary carpel.
4. Fruit of cycas similar, but no collar at base.

6. Fruit of Ferns, Mosses, Etc.

IX. SEED DISTRIBUTION.

Barbs or grappling devices.

Mechanisms for ejection, or propulsion of seeds.

Provision for floating on water.

Provision for floating in the air.

Seed used as food by animals.

Fruits used as food.

X. FACTORS INFLUENCING VEGETATION TYPES; OR ECOLOGICAL FACTORS.

Life and growth of plant dependent upon favorable conditions of environment.

Moisture, light, heat, air, etc.

Chemical constituents of the soil.

Different plants thrive under different conditions.

Not only individuals, but societies of plants likewise influenced by their environment.

Ecological factors.

1st, Physical factors.

2nd, Climatic factors.

3rd, Biotic factors.

1st, Physical factors.

1. Water.

a. Majority of plants need perceptibly moist soil.

b. Certain plants adapt themselves to dry conditions.

By enlarged root system.

By reduction of leaf surface.

c. Certain adapt themselves to wet conditions.

By reduction of roots and root hairs.

By reduction of leaf surface.

d. Influenced not only by the amount of water in the soil, but humidity of the air, drying effect of wind, effect of heat and light, chemical and physical properties of the soil, beating of waves on rocks, force of water in streams, etc.

Rainfall, or Precipitation.

Sometimes injurious.

3. Light.

a. Influence of light in photosynthesis.

b. Influence of light in growth of stem and position.

c. Influence of light in formation of chorophyll.

d. Many plants adapt themselves to certain degrees of light.

e. Majority of plants require abundance of light, but the amount must be varied according to the amount of moisture.

f. Shade plants have thinner and softer leaves than those receiving direct sunlight.

4. Heat.

a. Arctic and alpine plants vegetate at low temperature.

Ex., certain algae, fungi, etc.

b. Annuals require longer summer season than perennials.

c. Very high temperature injurious.

(1) Certain algae and some desert plants are able to endure a temperature of 70 degrees C. Some algae 80-89 degrees.

(2) Dry seeds and spores are able to resist a high temperature, which would kill some seeds.

d. Cardinal temperature points for different plant functions.

Acclimatization.

e. Protection from cold weather.

(1) Falling of leaves.

(2) Rosette habit of perennials.

(3) Low stature of arctic plants.

5. Wind. Both injurious and beneficial.

(1) Stunt and deform trees and shrubs.

(2) Drying effect.

(3) Pollination assisted.

6. Ground covers.

a. Snow cover.

(1) Checks radiation of heat.

(2) Sometimes deforms trees and shrubs.

(3) Hinders alternate thawing and freezing in temperate regions, thus protecting the roots.

(4) Conserves moisture.

(5) Glaciers destroy vegetation, but assist in soil formation.

b. Leaves and other plant remains.

(1) Protect from cold.

(2) Lessen radiation.

(3) Conserve moisture, etc.

c. Living plant covers, protection of shade plants in forests.

(1) From excessive heat and light.

(2) From cold.

(3) Air more humid, moisture conserved, etc.

7. Chemical conditions of the ground or water.

a. Derived from solutions of eroded and dissolved rock formations.

b. From decaying animal and plant remains.

c. From certain gases in rain water, salts of sea water, etc.

d. Elements necessary for plant growth.

Oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, iron, potassium, calcium, magnesium.

These are derived from the air, soil, certain compounds brought into solution by the plant, etc.

Certain substances found in solution in the soil which are harmful to the plants.

Modification induced by chemical conditions of soil.

8. Physical or mechanical conditions of the soil.

Difference of vegetation in rocky places, sandy soil, soil rich in humus, clay soils, peat moors, etc.

9. Physiography.

Mountains, oceans, rivers, etc., present barriers to migration, difference in altitude and temperature, exposure to light and sun's heat, and affect water content of the soil.

10. Mechanical adaptations in plants for seed distribution, etc.

2nd, Climatic factors.

1. Rainfall.
2. Temperature
3. Physiography.

3rd, Biotic factors.

1. Pollination by insects.
2. Distribution of seeds by birds and other animals.
3. Burrowing animals aid in soil culture.
4. Squirrels distribute nuts.
5. Man's agency.
6. Protection of plants among themselves.
7. Work of parasites, bacteria, etc.
8. Power of plant to relate itself to environment.

a. Growth and assumption of position by parts.
Diurnal movement leaves.
b. Movements.
Nocturnal movement leaves.
Epinasty and hyponasty.
Nutation of stems.

9. Active factor in plants.
10. Responsive factor in plants.

XI. ECOLOGICAL VEGETATION TYPES.

Meaning of vegetation type. Contrast with flora.
Responsive type of vegetation.
Warming's classification.

1. Mesophyte* societies, conditions of environment medium, Ex., North Temperature regions, except mountain heights, arid regions, sand dune areas, water, etc.
2. Xerophyte† societies, condition of environment severe.
Air, or soil, or both very dry.
Root absorption difficult.
Loss of water rapid.
Ex., of xerophytic situations,
1. Deserts, sand or gravel hills, rocky places, steppes and some prairies.
2. Soils or waters with large quantities of acids or salts.
3 Hydrophyte‡ societies.
Plants in water or in wet situations, or where air is very humid.
Water hydrophytes; aquatic.
Land hydrophytes: semiaquatic.
4. Halophyte§ societies.
Salt marsh plants.
Salt basin plants.

---

*Mesophyte. μέσος (middle), φυτόν (plant)
†Xerophyte. ξηρος (dry,) φυτόν
‡Hydrophyte. ὑδωρ (water), φυτόν
§Halophyte. ἅλος (salts), φυτόν

Schimper's classification.

1. Hygrophytes* : wet or damp situations=Hydrophytes.
2. Xerophytes.
   Conditions favoring loss of water; dry air, rarity of air, high temperature, light, movement air.
   Conditions hindering root absorption; dry soil, cold soil, excess of salts or acids in soil.
3. Tropophytes†=Mesophytes of Warming,—three main types.
   1. Deciduous trees and shrubs.
   2. Perennial herbaceous plants.
   3. Annuals and biennials.

Plant structures adapted to conditions of environment.

A. Normal plant condition.
   1. Uniform conditions throughout year or season favor normal plant.
      Damp tropical regions.
      Vegetation luxuriant.
      Humid areas of temperate regions.
   2. Extremes of conditions induce modifications, or plant succumbs.

B. Xerophytes or xerophytic structures.
   1. Physical factors which determine xerophytic vegetation two kinds.
      a. Those which decrease or limit water supply; relate to condition of soil.
      b. Those which accelerate loss of water by plant; relate to condition of air.
   2. Modifications designed for same purpose.
      a. To decrease loss of water.
      b. To increase absorption by roots.
      c. To conserve water for the plant.
   3. To decrease loss of water.
      a. Reduction of leaf surface.
      b. Protective covering or movements.
      c. Action and position of stomata.
      d. Total absence of foliage leaves.

---

†Tropophytes. τρέπω (turn), φυτόν
*Hygrophyte. ὑγρός (moist), φυτόν

e. Thorns and spines.
f. Water reservoirs.
g. Increase of root system.

C. Hydrophytes, or hydrophytic structures.
1. Water plants.
1. Provision for attachment.
2. Provision for floating.
3. Provision for aeration.
4. Provision for distribution of food.
5. Provision for fruiting.
6. Little development of mechanical tissue.
2. Swimming plants.
3. Land hydrophytes.

D. Mesophytes (Tropophytes).
1. Subject to medium conditions of environment. Extremes of heat in general detrimental to vegetation when accompanied by dryness. Compare resistance of seeds, spores ,etc.
2. Tropical region mesophytes. Plant in no danger from extremes in damp tropics. It reaches its highest development of foliage. It is luxuriant and permanent.
3. Temperate region mesophytes, or tropophytes, Growing season.
Resting season { cold. / dry.
Variation in conditions.
Provision against injury in fall of leaf.
Perennial herbaceous tropophytes.
Annuals and biennials.

E. Halophytes, or halophytic structures.
1. Xerophytic forms.
Salt marsh and salt basin plants. Modifications similar to those of plants in arid regions.
2. True halophytes.

F. Plant societies based on structural adaptation, as mesophytes, hydrophytes, xerophytes and halophytes, only applicable in extreme cases.

XII. LAWS AND LIMITS OF PLANT MIGRATION

Brief discussion of natural laws of movement of plants over earth.

1. "Distribution" generally used to mean area already occupied by different species. Sometimes also used to mean migration within own limits, or to distant regions.
2. Migration (also two-fold significance) in general refers to,—
    1. Movement plants to new territory.
    2. Movement plants back and forth in own territory.

1. Relation Plants to Earth's Surface as a Whole.

Northern hemisphere.
Southern hemisphere.
Land hemisphere (or continental).
Water hemisphere (or oceanic).
Opportunity for migration between continents.
Discontinuity of land sets barrier.

2. Life Regions, Zones and Areas.

Lines of plant migration.

1. Along lines of least resistance.
2. A complex problem.
3. Lines of least resistance.
    a. Belts of like temperature.
    b. Belts of like moisture content.
    c. Belts vary for different plants.
4. Life zones. Belts favorable for growth and reproduction of plants and animals.
    a. In general, transcontinental, not coincide with lines of latitude.
    b. Compare tropics.

Life regions.

1. Physiological constant of a species.
2. More accurate than isothermal.

Isothermal lines.

Regions first established in Northern Hemisphere by Alex. von Humboldt.

1. Boreal, or Northern.

2. Austral, or Southern.
3. Tropical.

Regions were separated along *isothermal* lines.

Data more or less arbitrary periods, not for growth and reproduction period.

Biothermal lines or biotherms more accurate.

Life Zones and Areas.

Lines of stress due to heat		Lines of stress due to rainfall or drought.
Boreal region	Arctic or Arctic-Alpine Zone.	
	Hudsonian Zone.	
	Canadian Zone.	
Austral region	Transition Zone	Alleghenian Area
		Arid Transition Area
		Pacific Coast Transition Area
	Upper Austral Zone	Carolinian Area
		Upper Sonoran Area
	Lower Austral Zone	Austroriparian Area
		Lower Sonoran Area
Tropical region		Humid tropical
		Arid tropical

The great lines of stress.

Heat and moisture.

Lesser lines of stress.

1. Small bodies of water.
2. Streams.
3. Variations in physical and chemical conditions.
4. Minor variations in physiography.

Total heat as limiting factor in north and south distribution of plants and animals.

1. Animals and plants limited in northward distribution by sum total of effective heat.

2. Limited in southward distribution by mean temperature for hottest part of year.
Note condition on Pacific coast.
a. High sum total effective heat.
b. Low mean temperature in summer.

Limiting factor for east and west distribution in U. S.
1. Mountain ranges.
2. Low precipitation in interior.

3. Methods and Causes of Plant Migration.

Advantages of plant migration.
Increases factor of safety for existence.
1. Larger number of individuals.
2. Safety of some assured in case of disaster in certain regions.

Structural characters favoring plant migration.
1. Seeds.
a. Buoyancy.
b. Grappling structures.
c. Food for animals.
d. Floating seeds.
2. Fruit.
a. As food for animals.
b. Exploding fruits.
3. Tumble weeds.
4. Floating of broken branches.
5. Prostrate or creeping plants.
6. Underground creeping stems or roots.

Causes of plant migration,—2 factors.
1. Biotic factors.
a. Influence of animals.
b. Initiated by plants
1st, Fertility of species—brings pressure.
2nd, Centrifugal habit of propagation.
3rd, Factor of adaptation, or acclimatization.
2. Physcial and climatic factors.
a. Wind, water, etc.
b. Tensions in fruits.
c. Climatic pressures, as in glacial epoch.

Action of glaciers.
Limits of glaciers.
Effect of cold wave on plant migration.
Forward and backward movement.
Evidences of plant migration in glacial times.

a. Distribution of plants in North America, Europe and Asia, and relation of flora (trees, algae, fungi, etc.)
b. Extinction of many in Europe and preservation in North America.
c. Fossil remains of plants in Arctic regions.

Present climatic pressures.

1. Humid tropics. Fertility of species.
2. Arctic.
   North and south movement meet and produce a lateral pressure.
3. Vicinity of mountains.
4. Vicinity of arid regions.

Fertility of aggressive species everywhere.
Barriers to plant migration.

1. Kinds of climate.
2. Kinds of soil.
3. Discontinuity of land.
4. Mountain chains.

Conflict of species in migration.

XIII. PLANT FORMATIONS

The General Formations.
Dominant vegetation type of a region is a *formation.*
General formations in 4 divisions.

1. Climatic Formations.
2. Edaphic Formations.
3. Aquatic Formations.
4. Culture Formations.

1. Climatic Formations.

Plant covering of earth not uniform.
Lack of uniformity of climate, topography and soil.
Two climatic factors { Moisture / Temperature

According to Schimper 4 climatic formations.

1st, The Arctic-Alpine Formation.

2nd, The Woodland Formation.

3rd, The Grassland Formation.

(Prairie)

(Plains)

4th, The Desert Formation.

2. Edaphic Formations.

Controlling factors.

Influence of soil or ground.

Open edaphic formations.

Close edaphic formations.

3. Aquatic Formations.

Fresh water, or limnetic formations.

Marine, or pelagic formations.

4. Culture Formations.

Vegetation of cultivated fields.

Vegetation of waste places.

5. Principal and Individual Formations, etc.

The principal formations.

Plant societies.

The individual formations.

The factors.

1. Physical, which relate to variation.
   a. In ground water.
   b. In physical and chemical condition soil.
2. Biological, which relate to struggle between species.

Result is, distinct groups of vegetation elements are formed in a society (or principal formation).

Such a group a formation.

Compare association, guild.

Pieces of mosaic, or zones. Typha formation (or typhetum), etc.

Single formations, and mixed formations.

Facies.

Vegetation forms.

Layers.

Zones.

Summary of Formations.

GENERAL FORMATIONS

1. Climatic (controlled by climatic factors)
   1. The woods or forest formation.
   2. The prairie formation.
   3. The plains formation.
   4. The desert formation.
   5. The Arctic-Alpine formation.
2. Edaphic (controlled by ground factors)
   6. Edaphic or soil plant formations.
      a. Rocky places.
      b. Sand areas.
      c. Marshes, moors, meadows.
      d. Alkaline areas, etc.
3. Aquatic (controlled by bodies of water)
   7. The aquatic formation.
      a. Fresh water formations.
      b. Salt water formations.
4. Culture (controlled by man).
   8. The culture formation.
      a. Cultivated areas.
      b. Waste areas.

Principal Formations (society) (controlled chiefly by distinct physiographic areas).

1. Layered.
2. Zoned.
3. Built up of vegetation forms.

Individual Formations (controlled by physical and biological factors).

1. Layered.
2. Zoned.

(One or several facies make up the formation).

Terminology of plant communities.

Complex character of plant societies.

XIV. FOREST SOCIETIES.

1. General Character of Forest Societies.

1. Extent of forest societies.
2. Complexity of the forest.

3. Different kinds of forests.
4. General structure of the forest.
    a. Floor.
    b. Canopy.
        Even.
        Compound or storied.
    c. Interior.
5. Longevity of the forest.
6. Longevity of the tree.

2. Boreal Forests.

1. Forests of the Hudsonian zone.
    Mainly spruces, firs and balsams, occasionally aspens and birches.
2. Forests of the Canadian zone.
    Similar to Hudsonian, but having some species which do not reach so far north, as some of the pines, hemlocks and deciduous trees.
3. Forests of the Austral zone, greater variations.
    Deciduous forests, highest development in Austral region.
        (1) In Alleghenian area, oaks, hickories, chestnuts, locusts, ashes, birches, aspens, spruces, firs, hemlocks, pines and other conifers.
        (2) In Carolinian area, tulip tree or whitewood, cucumber tree, persimmon, sweet gum, sourwood, chestnut oak, Spanish oak, yellow and scrub pine.
        (3) Autumn colors.
        (4) Fall of the leaf.
        (5) In Austroriparian or Louisianian area.
            Upland forest.
            Palustrine forest.
        (6) In Pacific Transition area.
            Douglas fir, Pacific cedar, western hemlock, sitka spruce, western white pine, redwood, big tree of California.
            Lumbering the redwoods.
            Preservation of the Big Trees.

3. Tropical Woods.

1. Classification according to Schimper,

(1) Evergreen forest.

Hygrophile, at least 30 metres high.
Lianas, climbing trees and vines.
Woody and herbaceous epiphytes.

(2) Tropophile, less in height.

Woody lianas, herbaceous epiphytes.
Few woody epiphytes.

(3) Savanna and thorn woods.

Grasses and herbs, few undershrubs in savanna woods.
Few grasses and herbs, many undershrubs in thorn woods.

2. Evergreen tropical forests.

(1) Evergreen forests remarkable for great numbers and luxuriance.
Noted for its herbaceous and woody epiphytes.

(2) Climax type of forest formation.

(3) Absence of climatic periodicity causes

1st, Almost continued growth.
2nd, Absence of bud scales on the buds.
3rd, Absence of uniformity in the time of defoliation.
4th, Extended flowering and fruiting period.
5th, Very dense forest canopy.
6th, Relatively small amount of humus.
7th, Structures for protection of leaves against water.
8th, Protection of leaves against heat and insulation.

3. Competition in evergreen tropical forests.

1st, Most dangerous competitors are parasites, epiphytes and lianas.
2nd, Epiphytes here reach their climax.
Ascend for light to the forest canopy.
3rd, Lianas also climb to the canopy.

4. Great value of tropical forests.
Very little known.

4. General Economics of the Forest.

1. Relation of forest to rainfall.
   (1) Forest dependent on rainfall.
   (2) Rainfall influenced by forest not so evident.
   (3) Cloud formation.
2. Importance of the forest in the disposal of rainfall.
   (1) Flood period extended.
   (2) Run off increased.
   (3) Injury lessened or prevented.
   (4) Serious results of floods in mountainous regions.
3. Regeneration of forests.
   (1) Natural regeneration takes place,
      1st, Through the seed.
      2nd, By growth of sprouts from the stump.
   (2) Shade endurers have the advantage in natural regeneration.
      Ex., hemlock spruce.
      Redwood regenerated by its abundant coppice.
      Big-trees by seedlings.
      Broad leaved trees by abundant coppice.
   (3) Artificial regeneration of forests.
      Silviculture.
      Systems of management in cutting and regeneration of forests.
         1st, The selection system.
         2nd, The system of clear cutting and regeneration by planting young trees or seed, or wind sowing.
         3rd, System of gradually thinning throughout.
         4th, Coppice system.
   (4) Protection of forests.
      By National and State governments for
         1st, Protection of game and other wild animals.
         2nd, Protection of species from destruction.

3rd, Holding in reserve water storage.
4th, Protection of lowlands from floods.
5th, Provision of healthful resorts.

4. Forest planting in unforested areas successfully attempted.
   (1) Afford shelter, firewood, building material.
   (2) Swamps reclaimed. Aided by eucalyptus.
5. Enemies of the forest.
   (1) Fires.
   (2) Carelessness of man.
   (3) Climatic and soil factors.
   (4) Biotic factors.
      1st, insects and animals feed upon leaves, buds, etc.
      2nd, parasites and wood destroying fungi.
         a. Some seed plants, rusts, mildews, molds, etc.
         b. Mushrooms most destructive. Gain entrance through bruises, broken branches, careless pruning, etc.
6. Scavenger members of the forest societies.
   Mushrooms of incalculable use in the disposal of waste material and its conversion into food for the living trees.

XV. THE PRAIRIE AND PLAINS SOCIETIES

1. Grassland Formations.

Types of grassland.

1. Savannas. Dry, warm, temperate, or subtropical countries, yet sufficient moisture to permit number of trees.
2. Prairie (meadows according to Schimper) cold temperate regions. Trees absent.
3. Plains or Steppes, formation more open.

Extent of prairie and plains in the United States.

Prairie,—100th meridian east to forests of Illinois, and Indiana, including most of Dakotas, Nebraska, Iowa, Southern Minnesota, Wisconsin, and large part of Kansas, Indian Territory, and extends north into Western

Manitoba and nearly all of Assiniboia and Saskatchewan.

Plains,—west to foot of Rocky Mountains and south and southwest to Sonora-Nevada desert.

2. Prairie Formations.

Tension line between forest and prairie not well marked, compare with skirmish line of armies—outposts.

Climatic factors the dominant ones in limiting forest and prairie.

1. Subordinate factors.
   a. Biotic, grazing of buffalo.
   b. Physical, prairie fires.
2. Evident that climatic the dominant factor.
   a. Greater amount of rainfall is in spring and summer when grass most needs it.
   b. This is time when seeds of trees would germinate and would die out in drought period.
   c. Firmness of soil and mat of grass hinder seedling getting a foothold.
   d. Heavy and drying winds in dry season and in winter cause excessive transpiration and scatter litter.

Prevailing grasses in prairie region.

1st type. "Sod formers," long rhizomes, close formations.
   Ex. Drop seed (Sporobolus asperifolius).
   Koehleria cristata.
   Eatonia obtusata.
   Panicum scribnerianum.

2nd type. Bunch grasses, tufts, tend to make open formations.
   Ex. Buffalo grass (Bulbilis dactyloides).
   Beard grass or broom sedge (Andropogon furcatus and scoparius).
   Grama grass (Bouteloa oligostachya), etc.

These two types are more or less mixed, but
   a. "Sod formers"="prairie grass formation" characteristic of lower prairies.
   b. "Bunch" grasses characteristic of arid regions of steppes west and southwest.

3. The Plains Formation.

The Great Plains of the United States.
- 100th meridian to foothills and southwest to desert.
- Prevailing grasses. Bunch grasses (buffalo, beard and Indian grasses). Here open formations.
- Other characteristic plants.
  - Sage brush (Artemisia tridentata).
  - Prickly pear cactus (Opuntia).
- Semidesert flora of southwest and Mexico tablelands.
  - Cacti, yucca, succulents.
  - Coarse shrubby growths (ex. Mesquit tree).
  - Sage brush and bunch grasses.

4. Edaphic Formations in Prairie Regions.

Different Areas.
1. Rivers (Forest and true meadows).
2. Sand hills.
3. Alkali areas and Bad lands.

Forest formations.
- Eastern element meets western element along Niobrara river (Pinus scopularum from Rockies).

Meadows, along river courses and around lakes.
- Intermediate between forest and prairie.
  - Elymus canadensis.
- Long stemmed "sod formers" Stipa spartea.
  - Agropyron pseudorepens, etc.
  - Subordinate, "Bunch grasses."

Sand-hills in Nebraska,
- Beard grass (A. scoparius) is dominant species.
  - Open formation.
- Subordinate plants in Sand-hills.
  - Xerophytic shrubs, herbs and other grasses.
  - Spring or vernal flora.
    - Cat's foot (Antennaria campestris).
    - Fennel leaved parsley (Peucedanum foeniculaceum).
    - Prairie clovers, etc.
  - Summer autumnal flora.
    - Golden rods, verbenas, amorpha, etc.

Sand plains, another beard grass (A. furcatus is dominant and formation closer, though often open).

Badlands of Nebraska and South Dakota.

Characters of environment.

a. Alkalinity of soil.
b. Loose and crumbling soil, "Buttes."
c. Dry air and intense heat.

Characteristic plants

Greasewood (Sarcobatus vermiculatus).
White sage (Eurotia lanta).
Bunch grasses and herbs rare or occasional.

Alkaline marshes and salt basins.

1. Meadows here and there by sod grass (Distichlis spicata, stricta and Agropyron pseudorepens).
2. Salty basins (Ruppia occidentalis and glasswort=Salicornia herbacea).
3. Salty soil near ponds.
   Salt bush (Atriplex, a chenopod).
4. These chenopods, greasewoods, adapt themselves to wide range.

XVI. DESERT PLANT SOCIETIES

1. Factors of Environment in the Desert.

The principal factors are:

1st, the very low rainfall.
2nd, the great amount of evaporation.
3rd, the alternation of rainy and dry seasons.

Some of the minor factors are as follows:

1st, the strong light (solar radiation), due to the absence of clouds which form a blanket over the earth.
2nd, high winds.
3rd, the physical and chemical character of the soil.

a. Salty or alkaline condition of the soil.
b. Calcareous soils.
c. The loose and crumbling condition of soil.
d. The topography of the region.

2. Characters of True Desert Plants.

True desert plants, perennials, to preserve root and stem through dry period.

1. Desert plants have to meet two general conditions.
   1st, dry hot atmosphere; 2nd, dry soil.

2. They meet it by

A. Reduction of transpiration.

1st, reduction in size of leaves, surface.
2nd, hairy coverings.
3rd, stomates deeply sunk.
4th, cuticle thickened.
5th, leaves dispensed with.
6th, stems shorter, with thick cuticle and and often hairy or waxy coverings.

B. Provision for water storage.

Thick, fleshy trunks or leaves, and roots.

C. Increased surface for root absorption.

Great length and branching.
Extend often to great depths.

Thorny or spiny character of desert vegetation.

3. The Sonora-Nevada Desert.

Location, valleys of great basin ranges.

Note Desert Botanical Laboratory.

Types of conditions are 4 in the region.

1. Oases.
   a. Along streams.
   b. By springs.
   c. By basins where there is ground water, hydrostatic water.
2. Higher altitude on mountain sides, coniferous forest, heavy snows, water doled out through a long period.
3. Elevated areas adjoining desert proper.
   Receives some moisture from mountains, cactus, yuccas, greasewoods, etc.
4. Desert area proper.
   (1) Two distinct floras.
      1st, annual or rainy season flora.
      2nd, perennial or true desert flora.
   (2) Rainy season depends on storm water, December-March.
      a. Water held in capillarity for several feet.
      b. Vegetation begins February and March.
      c. Evaporation from soil and transpiration.

d. Flora feels it and seeds.
e. Variations in size of plants different years.
f. Annuals best adapted to desert life. Pass dry time in seed.

(3) True desert flora, perennial.
a. Some tendency to flower in December but too cold for many species.
b. Flower and fruit in spring.
c. As hydrostatic water is used they change, i. e., tropophile habit. Two types,
(a) shed leaves, or
(b) die down to the ground or nearly so.
d. Character of plants, trees, shrubs, 3—4½ feet.
1. Compact, rounded growth.
2. Small, thick gray leaves.
3. Two types of shrubs.
Larrea tridentata. Numerous branches from subterranean source.
Peucephyllum schattii, tree like, dies.

(4) Few plants with thick roots.
(5) Suffrutescents—large number.
Lower portion shrubby and remains green.
Transpires and extended water system absorbs enough water.
(6) True desert plants dependent in dry period on hydrostatic water.
Rains very little, immediately re-evaporated.
(7) Trees (Mesquits) only around basins where there is ground water.
(8) Cacti, greasewood, chenopods.

4. General Consideration.

Season of maximum rainfall in different deserts.
Vegetation more dependent on ground water than rainfall.

Many perennials benefited by spring rains.
Places rare where there is absolutely no vegetation in deserts.
Oases populated by rank growth of trees and herbs.
Plants grouped into two ecological categories:

1. Those dependent on rain.
2. Those dependent on ground water.

Rainfall in the N. A. desert.
Climate in the N. A. desert.
"Dry lakes", swamps, soil alkaline.

Devoid of vegetation except around edges,—chenopods, sedges, grasses, etc., arranged in zones. On sand mesquit, chenopods, etc., other zones.

On elevations,—pines and junipers. Shrubs,—sage brush, etc.

XVII. ARCTIC AND ALPINE PLANT SOCIETIES.

1. Arctic Plant Societies.

Arctic zone of plant life.

"Cold waste", sometimes compared with desert.

Ground frozen to great depth.

Character of tree growth, at polar limit.

1. Stunted, often table like.
2. Dead tops,—often at quite regular distances.
3. Under deep snow bent and horizontal.
4. Growth in length slow in proportion to growth in diameter, but here very slow also.

Trees 83 mm. diameter (3 1-3 in.) 544 annual rings.

Polar tundra, related to heath or peat moors.

1. Heaths, saxifrages, dwarf willow, etc.
2. Lichen tundra (Cladonia, Alectoria, etc.).
3. Moss tundra (Polytrichum).

Conditions of environment.

1st, Temperature, long cold winter, low summer temperature.
2nd. Light, long winter night, continued daylight in summer.
3rd, Cold ground water in summer.
4th. High winds.
5th. Very dry air of long winter.
6th. Lessened precipitation, snow usually not deep.

Responsive type of vegetation. Stems always short.

1st. Radiate dwarf cushion type.
2nd. Rosette type.
3rd. Succulent type (Saxifrages).
4th. Reduced leaf system (Cassiope).
5th. Grasses like those of arid region.

Resistance to cold.

Plants have specific power to resist cold.

Flowers.

Generally brighter in color than temperate or tropical flowers.

Usually larger in proportion to size of stem and leaves.

Warm oases.

1. Protected from wind.
2. Slope toward south.
3. Ground thawed to greater depth.
4. Encourages a more luxuriant vegetation.

2. Alpine Plant Societies.

Schimper's divisions of mountains.

1. Basal region—analogous in climate to lowlands.
2. Montane region—analogous in climate to high places in lowlands.
3. Alpine region—no analogy in lowlands.
   a. In passing from basal to alpine region note zonal arrangement.
   b. General resemblance to arctic vegetation but different adaptations.
      Salix polaris and Saxifraga oppositifolia. Aerial parts more weakly developed in polar lands.
      Alpine character due more to physiological causes than to heredity.

Factors of alpine climate influencing plants.

1st. Decrease in precipitation.
2nd. Decrease in heat.
3rd. Rarity of atmosphere, favors,
4th. Strong solar radiation, and
5th. Strong radiation from ground.
} Results in great change temperature night and day.
6th. High winds.

7th. Alternation of night and day, not continuous light as in Arctic.

8th. Alternation heat and cold, again different from Arctic.

Characters of Alpine vegetation.

Characteristic vegetation above limit of tree growth.

Vegetation forms similar to those of polar lands.

Types of alpine plants according to Schimper.

1st. Elfin tree, short, gnarled, horizontal stems.

2nd. Alpine shrubs, dwarfed, creeping, much branched.

3rd. Cushion type, branching profuse and compact.

4th. Rosette type, short stems and strong roots.

5th. Alpine grasses, shorter leaves than grasses of lowlands.

Variation of individuals of same species.

Bonnier's exp. Alpine plants cut in two,

½ in Alpine climate, lowland soil.

½ in lowland climate and lowland soil.

In several places some of lowland halves took on character of lowland species.

XVIII STRAND FORMATION

1. Types of Strand.

General types of strand.

1. Xerophytic, or dry strand.
2. Hydrophytic, or moist strand.
3. Many gradations between these two types.

Variations as shown in the distribution of plants on the shore of Lake of the Woods, Minn.

Flora of the strand can only be understood when studied in connection with the physical geography of the region.

Note by MacMillan.

Variations in the shore.

1. Gradient of the shore.
2. Mechanical condition of the shore material.
3. Percentage of humus.

Kinds of strand.

1. Rocky shores, or Lithophytic.
2. Sandy shores, or Psammophytic.
3. Loamy shores, or Humiphytic.

2. Vegetation of the Beach or Strand.

Divisions of the strand.

Schimper's divisions.

1. The fore-shore ("Schorre")
2. The mid-shore.
3. The dunes.

MacMillan's division in strand formations of the Lake of the Woods.

1. The front-strand.
2. The mid-strand.
3. The back-strand.
4. Strand-pools.
5. Dunes.

The front-strand, or lower beach.

Surf prevents permanency of vegetation.

Lower algae, especially Cyanophyceae.

The mid-strand, or middle beach.

1. Subject to wave action only during high winds, but conditions severe on account of the rapid evaporation of water and radiation of heat.
2. Xerophytes,—grasses and sand herbs, then other plants.
3. Vegetation varies according to soil and exposure.
   Prunus mid-strand. Considerable wind exposure.
   Cornus mid-strand. Less wind and less humus, taller.
   Salix mid-strand. Inundation frequent.
   Sea rocket, saltwort, morning glories, etc.

Back strand.

Higher percentage of humus, less evaporation and radiation.

Vegetation more of a nitrophytic or thermophytic type.

Classification of back strand formation at Lake of the Woods.

1. Herbaceous back strand.
   a. Gramineous back strand.
   b. Mixed herbaceous back strand.
2. Shrubby back strand.
   a. Coniferous back strand.
   b. Populus back strand.
   c. Salix back strand.

d. Cerasus and Rosa back strand.
e. Mixed shrubby back strand.

3. Arboreal back strand.
   a. Coniferous back strand.
   b. Populus back strand.
   c. Salix back strand.
   d. Quercus back strand.
   e. Mixed arboreal back strand.

Another classification of strand formations.

Lower beach, near water's edge.

Middle beach=mid-strand.

Upper beach=back strand.

Dominant plants of middle beach on Lake Michigan.

American sea rocket.

Bug seed.

Sea-side spurge.

Atlantic and Gulf coast.

Sea rocket and spurge.

Seaward Zone.

Cakile fusiformis, Seablite (Dondia linearis).

Salsoia kali, Sea purslane (Sesuvium maritimum).

Large burr grass (Cenchrus macrocephalus).

Landward Zone

Same plant and tropical morning glories (Ipomoea pes-caprae, I. acetosaefolia, trailing wild bean (Strophostylis helvola).

Dominant plants of upper beach.

Artemisia caudata.

Artemisia canadensis.

Cnicus pitcheri.

Lathyrus maritimus.

Seaside spurge.

Oenothera biennis.

Agropyron dasystachyum.

Among shrubs, sand cherry and a species of willow.

Among trees, cottonwood, Populus monolifera and P. balsamifera.

Plants in similar formations of beach plants.

(Ipomoea pes-caprae and I. acetosaefolia).

III. Vegetation of the Dunes.

How dunes are formed.

Formed about certain grasses, and when large allow the development of trees and shrubs.

Kinds of dunes.

1. Stationary dunes.
    a. Embryonic.
    b. Mature.
2. Wandering or active dunes.

Dune formers require certain biological characters.

1. Compact growth to check wind and precipitate sand.
2. Perennial habit.
3. Rhizome propagation.
4. Ability of stems to grow out of the sand when buried.
5. Highly developed xerophytic structures.
6. Ability to stand root exposure.

The best dune formers as found in the Lake Michigan region according to Cowles are as follows:

1. Grasses with rhizome formation
    Ammophila arundinacea. Most abundant.
    Agropyron dasystachyum. (northward).
2. Grasses forming clumps.
    Elymus canadensis.
    Calamagrostis longifolia.
3. Shrubs.
    Salix adenophylla. Most abundant.
    Salix glaucophylla.
    Prunus pumila.
    Cornus stolonifera (or C. baileyi).
4. Trees.
    Populus monolifera.
    Populus balsamifera.

Size and age of dunes corresponds with their relation to the shore line.

Size of the vegetation depends upon the location of the dune.

Grasses, shrubs, open formations.

Grasses, thickets, trees, older shrubs.

Forests cover still older ones, which are continuous with forests on landward side.

Active or wandering dunes.

Easily blown about, because plant life is limited.

1st. As dunes grow in height plants further from ground water.

2nd. Only trees adapted to live there are short lived.

Often very complex.

Often cause great changes in the landward flora, sometimes causing great damage, which is sometimes successfully prevented by the planting of various dune formers.

Rejuvenated dunes.

Methods for checking movements of dunes.

XIX. PLANT SOCIETIES OF ROCKY AREAS, MEADOWS, AND MARSHES.

1. Vegetation of Rocky Places, and New Land.

Rocky shores.

Plants often modified by proximity to water (surf, etc.).

Zonal arrangement on sloping shores.

Azonal on irregular surface rock.

Formations usually open.

Lichens as pioneers in soil making.

Succession of plants as soil is formed.

Crevice plants.

Lichens, Cladonia, with several species.

Mosses, Hedwigia, Andræa (also on smooth rock).

Ferns, Polypodium, Dryopteris, Pellaea, Asplenium.

Herbs, harebell (Campanula), bluets (Houstonia), alum root (Heuchera).

Grasses, Arenaria stricta, Agrostis hiemalis, etc.

Shrubs, Cornus, Spiraea, some cedars.

Trees, white pine, also P. divaricatus, ash, trembling poplar, etc.

Transition of open formations into close ones.

1. Trent, 1888. Volcano krakatau three years after mountain covered with lava.

2. Schimper, Volcano Guntur in West Java mountains, in 1843 covered with glowing volcanic matter.
   Vegetation still quite open.
   Epiphytic shrubs and ferns here on ground.

3. Flauhault and Combres, 1894. Sandy and dune lowlands mouth of Rhine.
4. MacMillan, 1898, Lake of the Woods.
5. Cowles, 1898, Whitford, 1898, Kearney, Ganong, 1903, Fink, 1903.

II. Vegetation of Swamps and Moors.

Mud swamp or reed societies.

Bulrushes, reed grasses, cat-tail flag, arrow-leaf, etc.

Mostly xerophytes, some hydrophytes.

Where water is deeper vegetation is more like that of littoral zone of ponds or lakes.

Meadow swamp societies, progressed stage of mud swamp.

Grasses and sedges.

Sphagnum moor societies, or peat moor, also called "bog," "muskeag," etc.

1. Characterized by the presence or absence of lime.
2. Rich in nitrogenous matter, but combined with humus in form of humified albuminous bodies not available.
3. Humus acid retards absorption.
4. Poor in oxygen and bacteria and fungi.
5. Xerophytic vegetation, Cassandra, Andromeda polifolia, cranberry, Labrador tea, etc.
6. Insectivorous plants on moors.
7. High moors, work of Sphagnum.
8. Relation of vegetation to arctic in glacial times.

Plant atolls.

Topography of the atoll moor.

A floating inner zone.

Formation of the atolls.

A black spruce moor.

Fall of the trees on the marginal zone.

Dying of the spruce of the central area.

Other morainic moors.

Heaths. Heath plants the dominant vegetation.

a. Huckleberries, bear berries, cranberries.
b. But especially members of the Ericaceae, wild rosemary (Andromeda), dwarf cassandra or leather leaf (Chamaedaphne=Cassandra), heather (Calluna vulgaris).

Spruce and tamarack swamps.
Cane swamp societies.
Salt marsh societies.

1. Salt shores where gradient is low and soil nitrophytic.
2. Water brackish.
3. Plants xerophytic.
4. Structural adaptations in salt marsh plants.
    a. Abundance of air spaces. This is correlated with ability of plant to bear long inundation at high tide.
    b. Ability of root hairs to resist plasmolysis in highly concentrated sea water (ex. 90 per cent).
5. Individuals of same species more stunted close to water's edge when submerged for longer time.
    Examples, the maritime ruppia (Ruppia maritima), glasswort (Salicornia) Sedge spartina (Spartina stricta glabra).

Shores of marl ponds. Soil calcareous.
Vegetation often xerophytic.
Ex., shrubby cinquefoil (Potentilla fruticosa=Dasiphora fruticosa).

XX. AQUATIC PLANT SOCIETIES.

I. General Considerations.

How differ from sand swamp or mud swamp societies and gradation one to the other and to soil societies.
Relation of plants to water.

1. Some entirely submerged.
2. Some float on surface of water.
3. Some stems submerged, leaves on surface.
4. Some leaves erected above water, near semiaquatics.

Characters of aquatic plants.

1. Supported by the water.
2. Only a slight development of mechanical tissue.
3. Provided with air by large air spaces throughout the tissue.
4. Little development of root hairs.
5. Where roots are developed they are used chiefly as holdfasts.

Depth of growth. Regions of light.

1. Bright light region, or photic region.
    a. Macrophytes.
    b. Microphytes with photosynthesis.
2. Dimly lighted region, or dysphotic region..
    a. Microphytes stunted or fail.
    b. Few photosynthetic microphytes, ex., diatoms.

Dark region, or aphotic region.

Organisms not capable of photosynthesis, ex., bacteria.

Gulf of Naples bacteria found 800-3,500 ft.

Relation to substratum.

(Note on Schimper's use of Benthos, and the use of plankton and hemiplankton.)

1. Benthos fixed (βενθος =depths).
2. Plankton.
3. Hemiplankton.

Effect of the water on vegetation.

1. Vegetation dependent on varying degree of salinity.
    (1) Evaporation.
    (2) Fresh water.
2. Greatest salt content found in the Red Sea (4.3 per cent.)

Color due to Trichodesmium.

3. Ocean 3.5 per cent. mineral, 2.6 per cent. salt. Greater in tropical than in Arctic regions.
4. Movement of water affects the distribution of plants.
    a. Streams.
    b. Ebb and flow tide.

Marlponds. Affected by quantity of calcium carbonate (fresh water marlponds).

Inland lakes and salt ponds.

Vegetation of hot springs.

a. Beggiatoa.
b. Phormidium, Spirulina.
c. Anabaena, Gloeocapsa.

Affected by temperature.

1. Perennial pelagic algae no rest, some growth during winter.

2. Inland lakes and ponds in temperate regions.
    a. Perennials, seeds, spores, akinetes, hormogones.
    b. Annuals.
3. Note Lemanea in winter streams. Bacteria in ice.

Division of water plant societies.

1. Hydrophytic societies=fresh water or limnetic plants.
2. Halophytic societies=marine or pelagic plants.

II: Fresh water or Limnetic Societies.

Pond or inland lake societies.

Vegetation zonal.

1. Littoral zone, or semi-aquatics.
2. Mid zone, plants with floating leaves and slender stem.
3. Submerged zone, pond weed type and Chara.

Free floating forms are found in 1st and 2nd zones.

River or Fluvial plant societies.

Plants adapted to rapid and violent movement of water.

River-weed, mosses and algae, Podostemon.

Where water is quieter, pool or pond types.

Structural types of limnetic plants.

1. Quillwort type.
2. Waterlily type.
3. Pond weed type.
4. Duckweed type.
5. River-weed or fluvial type.

III. Marine or Pelagic Societies.

Mostly lithophytes and sea algae.

1. Benthonic forms mostly lithophytic.
2. Disk-like holdfasts of large forms.
3. Diatoms with gelatinous stems.
4. Large number of small ones, Epiphytes.
5. Many semiparasites among algae.
6. Few fungus parasites.

Very few attached to mud or sand bottoms.

Flora very scarce and corresponds with deserts.

Caulerpa, root like holdfasts.

Meadow or sea weed in shallow places.

Photic region 30-40 meters (100-125 ft.)

Upper photic zone divided into two strata, ebb and flow here.

1. Algae stunted, thick epidermis.
2. Best for growth. All pelagic seed plants and great mass of algal vegetation.

Lower photic zone divided into two strata with only algae found in this zone, different algae in different depths, below ebb.

Green algae.

Brown algae.

Red algae, sensitive to light, light decolorizes them.

XXI. SUGGESTIONS FOR PRACTICAL STUDY OF PLANT FORMATIONS

Student should have had a good course in elementary plant physiology and general plant morphology.

For independent study more required.

Work of beginning student can be done under the guidance of teacher.

Students can more easily detect a life relation, than they can determine many of the plants.

District selected for study should include if possible

Forest.

Low marshy areas.

Ponds or lakes.

These will usually include rocky, sandy, clayey areas, ravines, bluffs, meadows, etc.

Map the region, based on some good topographic map, like those being issued by the U. S. Geological Survey.

Studies should be supplemented by lectures and reading.

For practical work district selected may be in either

1. Coastal plain and continental valley district, or
2. Mountain districts, or
3. Division of territory recognized in Physical Geography.

The larger area may be divided somewhat as follows:

WOODLAND CLIMATIC REGION

Forested areas

Series of formations	Principal Formations
1. Upland series	Rock hill
	Gravel hill
	Sand hill
	Clay hill
2. Lowland series	Rock areas
	Gravel areas
	Sand areas
	Clay areas
	Loam areas
3. River series	Ravine
	River bluff
	Flood plain
	Mature river valley
4. Swamp series	Heath moor
	Mud swamp
	Water swamp
	Tamarack swamp
	Cypress swamp
	Mangrove swamp
5. Coastal series	Lake bluff
	Ocean bluff
	Sand strand or dunes
	Humus strand
	Coastal swamp.

Non Forested areas

Series of formations	Principal Formations
1. Edaphic series	Mud or reed swamp
	Sphagnum moor
	Heath moor
	Tamarack swamp
	Meadows
	Rocky places
	Sandy strand and dunes
	Salt marsh
	Alkali lands
	Shores of marl ponds
2. Aquatic series	Streams
	Ponds
	Lakes
	Salt seas
	Ocean
	Brackish waters
	Marl ponds
3. Culture series	Cultivated places
	Waste places

(no attempt is made here to subdivide the culture series.)

New features and combinations will present themselves in each district studied. The above outline must be modified to suit the particular case.

Montane districts.

1. Valley series.
2. Foothill series.
3. Basal series.
4. Montane series.
5. (Alpine series, beyond tree growth).

Formations.

1. If the area is properly mapped it will show the *principal formations,* covering the distinct physiographic areas, or edaphic areas, to be examined in detail.
2. The formations (individual formations)can be determined by discovering the dominant species.
    a. Sometimes one dominant species will constitute the formations.
    b. Sometimes there will be several dominant species in the individual formations.
    c. Chart the area occupied by different individual formations and name dominant species in each.
    d. If there are layers as in a forest or heath determine the prominent ones.
    e. On slope determine zonal formations.
    f. On shores of lakes or ponds with bowl-shaped basin determine the succession of forms.
        1st, Littoral zone of semiaquatics.
            1. Typha (or equivalent).
            2. Bulrushes (or equivalent).
            3. Arrow leaf (or equivalent).
        2nd, Floating zone.
            4. Pond lilies (or equivalent).
        3rd, Submerged zone.
            5. Pondweeds (or equivalent).
            6. Bass weed (or equivalent).
3. Note prominent physical characteristics of soil.
4. Note exposure to sun, wind, etc.

Secondary or subordinate species in a formation.

1. Species which are dominant in other similar places but subordinate here.
2. Species characteristic of the locality but never so abundant as to dominate the formation.
3. Species which are infiltrated in with the dominant vegetation form and mark this area off from others.
4. Guilds (or associates or companions), lianas, epiphytes, etc.
5. Parasites.
6. Wood destroying fungi.
7. Humus forming fungi, etc.

The general features of the study the teacher can illustrate.

1st, Lantern slides of vegetation and formations of regions not illustrated in the local flora.

2nd, By photographs illustrating the different physiographic or edaphic areas to be studied.

3rd, Obtain small collection of plants to illustrate various features of the study.

The student should keep a neat record, brief, but to the point.

Notes can be supplemented with charts, photographs, preserved plants, etc.

To chart extent and relations of plant formations

See MacMillan, Bull. Torr. Bot. Club, **23**, 502, 1896.

Pieters, the Plants of Lake St. Clair, Bull, Mch. Fish Com., No. 2, 1894, Lansing.

Ganong, Vegetation of Bay of Funday Marshes, Bot. Gaz., **36**, 351, 1903, and others.

BIBLIOGRAPHY

Atkinson, Geo. F., Heliotropism of Cassia marilandica, Bull. Torr Bot. Club, **21**, 81, 1894.

——————— Elementary Botany, 2nd edition, New York, 1899.

Studies of American Fungi ; Mushrooms, edible, poisonous, etc., Ithaca and New York: 2nd edition, 1901.

——————— First Studies of plant life, Boston, 1903.

Beal, W. J., Seed Dispersal, Ginn &.Co., Boston.

Bergen, J. Y., The Macchie of the Neapolitan coast, Bot. Gaz., **35**, 350-362, 416-426, 4 figs., 1903.

Berthoud, E. L., A peculiar case of plant dissemination. Bot. Gaz., **17**, 321-326, 1892.

Bonnier, G. and Flahault, Ch., Observations sur les modifications des végétaux suivant les conditions physiques du milieu, Annales des sciences naturelles, 6 serie, **7**, 1878.

——————— III. Étude expérimentale sur l'influence du climat alpin sur la végétation et les fonctions des plantes. Bull. de la Soc. bot. de France, **35**, 1888.

——————— IV. Études sur la végétation de le vallée de chamonix et de la Chaine du Mont Blanc. Revue générale de botanique, **1**, 1889.

——————— I. Culturés expérimentales dans les hautes altitudes. Compt. ren. de l'Acad. des sci. de Paris, **120**, 1890.

——————— II. Influence des hautes altitudes sur les fonctions des végétaux. Ibid., 1890.

——————— VII. Cultures expérimentales dans les Alps et les Pyrenées. Revue générale de botanique, **2**, 1890.

——————— V. Les plantes arctiques comparées aux memes espèces des Alpes et des Pyrenés. Ibid., **6**, 1894.

——————— VI. Recherches expérimentales sur l'adaptation des plantes au climat alpin. Annales des sciences naturelles, 7 serie, **20**, 1895.

Bornet, Ed., et Flahault, Ch., Sur quelques plantes vivant dans le test calcaire des mollusques. Bull.de la Soc. bot. de France, **36**, 1889.

Bray Wm. L., Plant geography of North America. The relations of the North American flora to that of South America, 1-8, 1900. Science, N. S., **12**, 709-716, 1900.

——————— The botanical relations of the vegetation of Western Texas, The Bot. Gaz., **32**, 9-123; 195-217; 262-291, 24 text figs., 1901.

Britton, N. L., On the general geographical distribution of North American plants. Am. Assn. Adv. Sci., **39**, 322-327, 1890.

Britton, W. E., Vegetation of the North Haven sand plains. Bull. of the Torr. Bot. Club, **30**, 571-620, pl. 23-28, 1903.

Bruncken, E., North American forests and forestry, pp. 262, New York, 1900.

Buck, P. D., Beiträge zur vergleichenden Anatomie des durchlüftungssystems. Inaugural dissertation. (Bot. Gaz., **36**, p. 473, 1903.)

Campbell, D. H., University text book of botany, New York 1902.

Clements, F. E., A system of nomenclature for phytogeography. Engler's bot. jahrbuch, **31**, Beiblatt, heft 4 and 5. 1-20, 1902.

———————— The development and structure of vegetation, Bot. Survey of Nebraska, 5-175, 1904.

Costantin, J., Les végétaux et les milieux cosmique, pp. 292, 171 figs., Paris, 1898.

———————— La nature tropicale, pp. 315, 166 figs., Paris, 1899.

Coulter, J. M., Plant relations, New York, 1899.

Coulter, S. M., An ecological comparison of some typical swamp areas. 15th ann. rept. Mo. bot. garden, 39-71, pl. 1-24, 1904.

Coville, F. V., Botany of the Death valley expedition. Contributions U. S. Nat. Herb., **8**, 1898.

Coville, F. V. and MacDougal, D. T., Desert botanical laboratory of the Carnegie Institution, I-VI+1-58, plates 29, figs., 4, Washington, 1903.

Cowles, H. C., The ecological relations of the vegetation on the sand dunes of Lake Michigan, Bot. Gaz., **27**, 95-391, 1899.

———————— The physiographic ecology of Chicago and vicinity; A study of the origin, development, and classification of plant societies, the Bot. Gaz., **31**, 73-108; 145-182, 1901.

Dandeno, J. B., The mechanics of seed-dispersion in Ricinus communis. Bull. Torr. Bot. Club, **31**, 89-92, 1904.

Davis, B. M., The vegetation of the Hot Springs of Yellowstone Park. Science, N. S., **6**, 145-157, 7 figs., 1897.

Davis, Chas. A., A second contribution to the Natural History of Marl., Journal of Geology, **9**, 491-505, 1901.

DeCandolle, A., Géographie botanique raisonée, **1**, **2**, Genève, 1855.

Dieck, Dr. G., Die Moor- und Alpenpflanzen (vorzugsweise Eiszeitflora) des Alpengartens Zöschen bei Merseberg und ihre Cultur, pp. 1-88, 1899.

Dorner, H. B., Effect of the composition of the soil upon the minute, structure of plants, Pro. Indiana Acad. Sci., 284-290, 1901.

Drude, O., Die Florenreiche der Erde, Petermann's mittheilungen ergänzungsband, **16**, pp. 174, 3 plates, 1890.

———-— Atlas der Pflanzenverbreitung, Gotha, 1877.

———-——— Handbuch der Pflanzengeographie, Stuttgart, 1890

Engler, A., Versuch einer Entwickelungsgeschichte der Pflanzenwelt, **1**, **2**, 1879, 1882.

———————— Die Pflanzengeographische gliederung Nordamerikaserlaüert an der nordamerikanischen Anlage des neuen Königlichen botanischen gartens zu Dahlem-Steglitz bei Berlin. Separate reprint from Notizblatt Königl. Bot. Gart., Appendix 9, 8vo., pp. I-IV+

1-94 with plan and distribution map, Leipzig., (Bot. Gaz., **34**, 318, 1902.)

Farmer, J. B., On the mechanism which is concerned in effecting the opening and closing of tulip flowers, the New Phytologist, 56-58, 1902.

Farmer, J. B., and Chandler, S. E., On the influence of an excess of carbon dioxide in the air on the form and internal structure of plants. Proc. Royal Soc. **70**, 413-423, 1902.

Fernow, B. E., The battle of the forest., Nat. Geographic Mag., **6**, 127-148, pl. 718, fig, 1, 1894.

Fink, Bruce, Some Talus Cladonia formations. (with 5 illustrations), Bot. Gaz,, **35**, 195-208, 1903.

Fisher, R. T., The redwood. I. A study of the redwood., U. S. Dept. of Agri., Bureau of Forestry, Bull. No. 38, 1-28, pl. 1-12, 1903.

Flahault, C., et Combres, P., Sur la flore de la Camargue et des alluvions du Rhone., Bull. Soc. Bot. France, **41**, 37-58, 1894.

Flahault, Ch., A project for phytogeographic nomenclature, Bull. Torr. Bot. Club. **28**, 391-409, 1901.

Frank, B., Ueber die auf wurzelsymbiose beruhende ernährung gewisser Bäume durch unterirdische Pilze, Ber. deutsch. bot.Gesell ., **3** 128-145, Taf. X, 1885.

Ganong, W. F., Upon raised peat bogs in the province of New Brunswick, Trans. Royal Soc. Canada, 2nd ser., 1897 -98, 3rd ser., 4, 131-163, 1897.

———————— Notes on the natural history and physiography of New Brunswick, Bull. Nat. Hist. Soc. New Brunswick, No. 16, 50-52. 1898.

———————— Wind-effects on vegetation on the Isthmus of Chignecto, Bull. Nat. Hist., Soc. New Brunswick, No. 17,134-135, 1899.

———————— Preliminary outline of a plan for study of the precise factors determining the features of New Brunswick vegetation. Bull. Nat. Hist. Soc. New Brunswick, No. 17, 127-130, 1899.

———————— A preliminary synopsis of the grouping of the vegetation (Phytogeography) of the province of New Brunswick, Bull. Nat. Hist. Soc. New Brunswick, No. 21, 47-60, 1902.

———————— The vegetation of the Bay of Funday salt and diked marshes; an ecological study, with 16 figures and maps, Bot. Gaz. **36**, 161-186, 280-302, 349-367, 429-455. 1903.

———————— Cardinal principles of ecology, Science, **19**, 493-498, 1904.

Griffiths, D., Forage conditions and problems in eastern Washington, eastern Oregon, northeastern California, and northwestern Nevada. U. S. Dept. of Agri., Bureau of Plant Ind., Bull. No. 38, 9-51, pl. 1-9, 1903.

Gerhardt, Paul, Handbuch des deutschen Dunenbaues, pp. 1-28+1-656, figs., 445, Berlin, 1900, (Bot. Gaz. **35**, 139, 1903.)

Gibbs, R. E., Phyllospadix as a Beach-Builder, the Am. Naturalist, **36**, 101-109, 1902.

Gifford, J., Practical Forestry. New York. 1902.

Goebel, K., Pflanzenbiologische Schilderungen. Theil II. VI. Wasser-Pflanzen. Marlburg, 1893.

Graener, P., Die heide norddeutschlands und die sich anschliessenden formationen in biologischer Betrachtung, Leipzig, 1901. (Bot. Gaz., **35**, 293, 1903.)

Gray, A., The flora of Japan, Mem. Am. Acad , N. S., **6**, 1859.

——— Sequoia and its history, Proc. Am. Assn. Adv. Sci., **21**, 1-31. 1872.

—— —— Forest geography and archaeology, Am. Jour. Sci. 3rd ser., **16**, 85, 183, 1878.

——— The pertinacity and predominance of weeds., Am. Jour. Science and Arts, 3rd ser., **18**, 161, 167, 1879.

Grisebach, A., Die vegetation der Erde nach klimatischen Anordnung, Leipzig, 1872. French edition by Tchiatcheff, Paris, 1877.

Groom, P., On a new saprophytic monocotyledon, Ann. Bot., **9**, 45-58, pl. 9, 1895.

——— On Thismia Aseroe (Beccari) and its mycorhiza, Ann. Bot., **9**, 327-361, pl, 13, 14, 1895.

Haberlandt, H., I. Anatomisch-physiologische untersuchungen über das tropische Laubblatt. (I.) Ueber die transportation einiger tropenpflanzen. Sitzungberichte der Wiener akademie, **101**, Abth. 1, 1892.

——————— Vol. 2 (II) Ueber wassersecernirende und -absorbirende Organe. (1 Abhandl)., **103**, Abth. 1, 1894.

——————— Ibid, **104**, Abth, 1, 1895.

Halsted, B. D., The migration of weeds. Proceedings Am. Ass'n. Adv. Sci , 304-312, (1890), 1891.

Harper, R, M., Botanical explorations in Georgia during the summer of 1901, Bull. Torr. Bot. Club, **30**, 282-295, II. Noteworthy species., Bull. Torr. Bot. Club, **30**, 319-342, 1903.

——— Explorations in the coastal plain of Georgia during the season of 1902, Bull. Torr. Bot. Club, **31**, 9-27, 1904.

Harshberger, J. W., A phyto-geographic sketch of extreme southeastern Pennsylvania, Bull. Torr. Bot. Club, **31**, 125-159, 1904.

Heer, Flora fossilis arctica, and suppls., 1864-78.

Hill, E. J., Flora of the White Lake region, Michigan, and its ecological relations (with map),, Bot. Gaz., **29**, 419-436, 1900.

Hitchcock, A. S., Ecological plant geography of Kansas, Trans. Acad. Sci. St. Louis, **8**, 55-69, 1898.

——————— Methods used for controlling and reclaiming sand dunes, U. S. Dept. Agri., Bureau of Plant Ind., Bull. No. 57, 9-36, pl. 1-9, 1904.

Holzinger, J. M., Lake McDonald and vicinity, Bull. of the Am. Bureau of Geography, **1**, 3-17, 1900.

Kamienski, Fr., Les organes végétatifs du Monotropa hypopitys, Memoires de la Société nationale des sciences naturelles de Cherbourg, 1882.

Kearney, T. H., The plant covering of Ocracoke Island; a study of the ecology of the North Carolina strand vegetation. Contrib. U. S. Nat. herb, **5**, 263-319, 1900.

———————— Report on a botanical survey of the Dismal Swamp region, Contrib. U. S. Nat. Herb, **5**, No. 6, pp. I-X+321-585, 1901.

———————— Are plants of sea beaches and dunes true halophytes Bot. Gaz. **37**, 424-436, 1904.

Kerner, von Marilaun, Anton, Natural history of plants, English, trans. by Oliver, 1894.

———————— Pflanzenleben, zweite ganzlich neubearbeitete auflage, Erster band; Gestalt und leben der Pflanze. 8vo. pp. I-XII+1-766, figs. 215, plates 34 (21 colored),1896 Zweiter band; Die Geschichte der Pflanzen, 8vo. pp. I-XII+1-778, figs. 233, plates 30, (19 colored), map 1, 1898, Leipzig and Vienna, (Bot. Gaz., **26**, 361, 1898.)

Kihlman, A. O., Pflanzenbiologische schilderungen aus Russisch-Lappland. Acta Societatis pro Fauno fennica, **6**, 1890.

Kindermann, V., Über die auffallende widerstandskraft der schliesszellen gegen schädliche einflûsse. Sitzb. Akad. Wiss. Wien. Math.-Nat. Classe., Abth. 1, 3. 490-509, 1902.

Kjellman, F. K., Aus dem Leben der Polarpflanzen. In Nordenskjöld, Studien und Forschungen, veranlasst durch meine Reisen im hohen Norden, Leipzig, 1885.

Knuth, Paul, Handbuch der Blütenbiologie unter zugrundelegung von Hermann Müller's werk "Die befruchtung der Blumen durch Insekten" **1**, pp. 400, **2**, part 1, pp. 697, Leipzig, 1898 (Bot. Gaz., **26**, p. 358, 1898.)

Lagerheim, G. de, II. Bidrag till Kännedomen om snöfloran i Lulae Lappmark. Botaniska Notizer, 1883.

———————— I. Die schneeflora des Pichincha. Ber. d. deutsch. bot. Gesell. **10**, 1892.

Lamborn, R. H., The knees of the Taxodium distichum, Am. Nat., **24**, 333-340, pl. 12, 1890.

Livingston, B. E., The distribution of the upland plant societies of Kent county, Michigan (with map.,) Bot. Gaz., **35**, 36-55, 1903.

———————— Physical properties of Bog water, Bot. Gaz., **37**, 383-385, 1904.

Lloyd, F. E. and Tracy, S. M., The insular flora of Mississippi and Louisana, Bull. Torr. Bot. Club, **28**, 61-101, 1901.

MacDougal, D. T., Seed dissemination and distribution of Razoumofskya robusta (Engelm.) Kuntze, Minn. Bot. Studies, **2**, 1 169-173, pl. 15-16, 1899.

———————— Symbiosis and Saprophytism, Bull. Torr. Bot. Club, **26**, 511-530, pl. 367-369, 1899.

———————— Symbiotic saprophytism, Ann. Bot., **13,** 1-47, pl. 1-2, 1899.

———————— Soil temperatures and vegetation, Bull. N. Y. Bot. Garden, No. 44, 1-12, 1903.

———————— Some aspects of desert vegetation, The Plant World, **6,** 249-257, pl. 32-36, 1903.

———————— Some correlations of leaves, Bull. Torr. Bot. Club, **30,** 503-512, 1903.

———————— The influence of light and darkness upon growth and development, Mem. N. Y. Bot. Garden, II, pp. 319, figs. 176, N. Y. Bot. Garden, 1903.

MacDougal, D. T., and Lloyd, F. E., The roots and mycorhizas of some of the Monotropaceae, Bull. N. Y. Bot. Garden. **1,** 419-428, 1900.

MacMillan, C., Les plantes Europeennes introduit dans la vallée du Minnesota, Rev. Gen. Botan., **3,** No. 7, 1891.

———————— Relative altitude of the Rocky and Appalachian mountain Systems as influencing the distribution of Northern plants, Am. Nat., **25,** 146-150, 1891.

———————— Relationships of the metaspermic flora of the Minnesota valley, The Metaspermae of the Minnesota Valley, Rept, Survey Bot. Ser. 1, 582-612, 1892.

———————— On the formation of circular Muskeag in Tamarack swamps, Bull. Torr. Bot. Club, **23,** 500-507, pl. 279-281. 1896.

———————— Observation on the distribution of plants aloug shore of Lake of the Woods, Minn. Bot. Stud. I (Bull. 9, Survey Bot. Ser. II,) 949-1023, pl. 70-81, 1897.

———————— Notes for teachers on the geographical distribution of plants, Jour. School Geography, **1,** 1-6, 1897.

———————— Minnesota plant life, pp. 568, 238 figs. Rept. Surv. Bot. Ser. 3, St. Paul, 1899.

Magnin, A., Recherches sur la végétation des lacs du Jura Suisse Revue gener. de Botan., **5,** 1893.

———————— Contributions a la connaissance de la flore des Lacs du Jura Suisse, Bull. Soc. bot. de France, **41,** 1894.

Magnus, W., Studien an der endotropen Mycorhiza von Neottia nidus avis L., Jahrbüch. für wiss. Bot. **35,** 1-68, pl. 4-6, 1900.

Merriam, C. H., Results of a biological survey of the San Francisco mountain region and desert of the Little Colorado, Arizona, U. S. Dept. of Agri., Div. of Ornithology and Mammalogy, North American Fauna, No. 3, pp. 1-136, pl. 1-13, 5 maps, 1890.

———————— Laws of temperature control of the geographic distribution of terrestrial animals and plants, Nat'l geogr. mag., **6,** 229-238, 3 col. maps, 1894.

———————— Life zones and crop zones of the U. S., U. S. Dept. of Agri., Div. of Biological Survey, Bull. No. 10, 9-79, 1898.

Message from the President of the U. S., transmitting a report of the secretary of agriculture in relation to the forests, rivers, and mountains of the Southern Appalachian region, Washington, 1902

Middendorff, A. V., Die Gewächse Sibiriens. In Sibirische Reise, **4,** Theil 1, Lief. 4, 1864.

Mohr, Chas., Plant life of Alabama. Contrib. U. S. Nat. Herb., **4,** 11-921, pl. 1-13, 1901.

Nathorst, A. G., Studien über die flora Spitzbergens, Engler's Jahrbücher, **4,** 1883.

Needham, J. G., The fruiting of the blue flag (Iris versicolor L.), American Naturalist, **34,** 361-386, 1900.

Pammel, L. H., Old lake vegetation in Hamilton county, Iowa. Some ecological notes on the Muscatine flora, The Plant World, **2,** 1898.

Peck, Chas., Plants of the summit of Mt. Marcy, Bull. 5, No. 25, N. Y. State Mus. Nat. Hist. Rept. Botanist for 1898, p. 657-661, 1899.

Pieters, A. J., The plants of Lake St. Clair, Bull. of the Mich. Fish Commission, No. 2, 3-10, 1894.

———— The plants of western Lake Erie, with observations on their distribution, U. S. Com. of fish and fisheries, 57-79, pl. 11-20, 1901.

Pinchot, G., A short account of the big tree of California, U. S. Dept. of Agri., Div. of Forestry, Bull. No. 28, 7-30, pl. 1-15, 2 maps, 1900.

Plumb, C. S., The geographic distribution of cereals in North America, U. S. Dept. of Agri., Div. of Biological Survey, Bull. No. 14, 5-24, 3 fig., 1898.

Pound, R., and Clements, F. E., The vegetation regions of the prairie province, Bot. Gaz., **25,** 381-394, pl. 21, 1898.

———————————— The Phytogeography of Nebraska. 1. General Survey, 2nd edition, pp. 442, with maps, 1900.

Preston, C. E., Structural studies on southwestern Cactaceae, Bot. Gaz., **32,** 35-55, fig. 1-9, 1901.

Ramaley, F., Remarks on the distribution of plants in Colorado, east of the Divide, Postelsia, the yearbook of the Minnesota Seaside Station, 21-53, pl. 4-9, 1901.

Reed, H. S., The ecology of a glacial lake, Third Rept. of the Mich. Acad. of Sci., 43-45, 1901.

———— A botanical survey of the Huron River Valley, Bot. Gaz., **34,** 125-139, 1902.

Rowlee, W. W., Adaptation of seeds to facilitate germination, Science, **20,** 189-190, 1892.

———————— The swamps of Oswego county, N. Y., and their flora, The American Naturalist, 690-800, 1897.

Schaffner, J. H., Observations on Helianthus annuus, Bot. Gaz., **25,** 395-403, 1 fig., 1898.

———————— The nutation of Helianthus, Bot. Gaz., **29,** 197-200, 8 figs., 1900.

Schimper, A. F. W., Plant Geography upon a physiological basis. English translation, W. R. Fisher, revised and edited by P. Groom, and I. B. Balfour, pp. I-XXX + 1-839, figs. 501, with maps, Oxford, 1903.

Schimper and Schenk, Palaeophytologie, Zittel's Handb. d. Palaeont., **2** (1879-1890).

Setchell. W. A., The upper temperature limits of life, Science. N. S., **17,** 934-937, 1903.

———————— On the classification and geographical distribution of the Laminariaceae. Trans. Conn. Acad. Sci., **9,** 333-375, 1903.

Shaler, N. S., Preliminary report on Sea-Coast swamps of the Eastern U. S., Sixth Ann. Rept. U. S. Geol. Surv., 353-398, (1884-85), 1885.

———————— The origin and nature of soils. Tenth Rept. U. S. Geol. Surv., 213-345, 1891.

———————— General account of the fresh water morasses of the United States, with a description of the dismal swamp district of Virginia and North Carolina, U. S. Geol. Surv. 12th Rept., 255-339, 1888-89, pt. I, Geology.

———————— — Beaches and tidal marshes of the Atlantic coast. National Geographic Monographs, New York, American Book Co., 1895.

———————— The origin and nature of soils, Twelfth Ann. Rept. U. S. Geol. Surv., 1892 (Also, the geological history of harbors, Thirteenth Report, 1894).

Shaw, Chas. H. The development of vegetation in the morainal depressions of the vicinity of Woods Hole, Bot. Gaz., **33,** 437-450, 1902.

Shriner, F. A, and Copeland, E. B., Deforestation and creek flow about Monroe, Wisconsin, Bot. Gaz., **37,** 139-143, 1904.

Smith, R., Plant Associations, Nat. Sci., **14,** 109-120, 1899.

———————— Botanical survey of Scotland I, Edinburgh District II, North Pertshire District, Scott. Geog. Mag., **16,** 385-416 ; 441-467, 1900.

Snow, L. M., Some notes on ecology of the Delaware coast., Bot. Gaz., **34,** 284-306, 1902.

Snow, J. W., The plankton algae of Lake Erie, with special reference to the Chlorophyceae, U. S. fish com. Bull., pp. 369-394, pl. 1-4, 1903.

Spalding, V. M., The rise and progress of ecology, Science, N. S. **17,** 201-210, 1903.

Stahl, E., Der sinn der mycorhizenbildung, Jahrb. f. wiss. bot., **34,** 539-668, 1900.

Stevens, F. L., Nutation in Bidens and other genera, Bot. Gaz., **35,** 363-366 4 figs., 1903.

U. S. Geog. Surv., 20th Ann. Rept., Part V, Forest reserves, I-XVIII+ 1-498, 159 plates, 1898-1899.

Wahrlich, W., Beitrag zur kenntniss der orchideenwurzelpilze Bot. Zeit., 1886.

Ward, H. Marshall, Some recent publications bearing on the question of the sources of nitrogen in plants, Ann. Bot. **1,** 324-357, 1888.
Warming, E.. Ueber Grönland's vegetation. **10,** 1888.
———————— Lehrbuch der oekologischen Pflanzengeographie, Berlin, 1896.
Watson, Sereno, The relation of the Mexican flora to that of the United States, Proc. A. A. A. S., **39,** 291-292, (1890), 1891.
Wiesner, Elemente Wissenschaftliche Botanik, 1890.
Webber, H. J., Studies on the dissemination and leaf reflexion of Yucca aloifolia and other species, 6th Ann. Rept. of the Missouri Botanical Garden, St. Louis, Mo., pp. 91-112, pl. 45-47, 1895.
———————— The water hyacinth and its relation to navigation in Florida, Bull. No. 18, U. S. Dept. of Agri., Div. of Botany, 7-20, 1897.
Weld, L. H., Botanical Survey of the Huron River Valley, II. A Peat bog and Morainal lake (with 6 figs.), Bot. Gaz., **37,** 36-52, 1904.
Wheeler, W. A., A contribution to the knowledge of the flora of southeastern Minnesota, Minn. Bot. Studies, **2,** part 4, 353-416, pl. 21-27, 1900.
Wilson, W. P., The development and function of the so-called cypress "knees", together with a short consideration of the natural habitat of the tree., Proc. Am. Assn. Adv. Sci., 329-330 (1890), 1891.
Whitford, H. N., The genetic development of the forests of northern Michigan ; a study in physiographic ecology, Bot. Gaz., **31,** 289-325, 1901.
Whitney, M., and Cameron, F. K., The chemistry of the soil as related to crop production, Bull. 22, Bureau of Soils, U. S. Dept. of Agri., pp. 71, 1903.
Wiesner, Julius, Biologie für Pflanzen, mit einen Anhang : die historische entwicklung der botanik, pp. I-VIII + 1-340, figs. 78 and 1 map, Vienna, 1902.
Winchell, Distribution of forest and prairie in Minnesota, Min. Rep. Geol. and Nat. Hist. Surv., **1,** 136, 1884.
Wittrock, V. B., Om snöns och isens flora. Nordenskiöld's Studier och forskningar af mina resor i höga norden. Stockholm, 1883.

PRESS OF THE
ITHACA PUBLISHING CO.
ITHACA, N. Y.